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USING INFRARED SPECTRAL FEATURES TO PROBE CIRCUMSTELLAR DUST SHELLS AROUND COOL STARS

Michael P. Egan and Chun Ming Leung
Rensselaer Polytechnic Institute, Troy, New York 12180–3590, USA

IRAS observations of cool stars provide low resolution spectra in the mid–infrared (7.8–22 μm) and also give fluxes at four wavelength bands (12, 25, 60, and 100 μm) from which color–color diagrams are constructed. The latter have been used to study the evolution of these stars, e.g., as an O–rich star evolves to become a C–rich star and its detached dust shell moves further away, its evolution can be tracked on a color–color diagram (Willems, 1987; Chan and Kwok, 1988).

A major factor in determining the position of either C–rich and O–rich stars on the 12–25–60 μm color–color diagram is the presence of spectral features in the mid–IR. O–rich stars show a 9.8 μm silicate feature, while C–rich stars have a SiC feature at 11.2 μm. IRAS observations (Little–Marenin, 1986) indicate that the SiC feature is quite narrow and uniform in shape showing little variation from star to star. The full width at half maximum (FWHM) is 1.6 ± 0.15 μm. On the other hand, the shape of the silicate feature varies widely among the O–rich stars, with a FWHM ranging from 2 to 3 μm.

The characteristics of circumstellar dust shells should manifest themselves both in the flux spectrum and in the details of the spectral features. To provide a coherent interpretation for these IRAS observations, we have constructed models (using the radiative transfer code of Egan *et al.*, 1988) of dust shells around O–rich and C–rich stars. We used realistic grain opacities which include spectral features of varying intrinsic widths (e.g., gaussian features at 10 μm with half width at half maximum of 0.5 and 1.0 μm). Applying various observational constraints to the models, the following conclusions emerge:

(1) The difference in variations of the shape of SiC and silicate features is due to the smaller intrinsic width of the SiC feature in the presence of varying dust temperature distributions. Spectral features with greater intrinsic width are more sensitive to changing physical conditions in the dust shell (see figure).

(2) The observed differences in the width of the silicate feature in O–rich stars are most likely due to variations in the dust shell distance from the star. Variations in shell optical depth, dust density distribution, or grain composition cannot easily account for the range of shifts observed in the silicate feature.

(3) Variations in the luminosity of the central star and in the dust shell parameters produce distinct effects on the position of a star on color–color diagrams. In particular, as the distance of the dust shell from an O–rich star increases, the intensity on the red side of the silicate feature is enhanced, resulting in a systematic shift in position of the star on the 12–25–60 μm color–color diagram. Hence a correlation between the shifts of the silicate features observed in O–rich stars and their corresponding positions on the color–color diagram would provide strong

support for the hypothesis that O–rich stars evolve to form carbon stars as their O–rich dust shells are detached (Willems, 1987)

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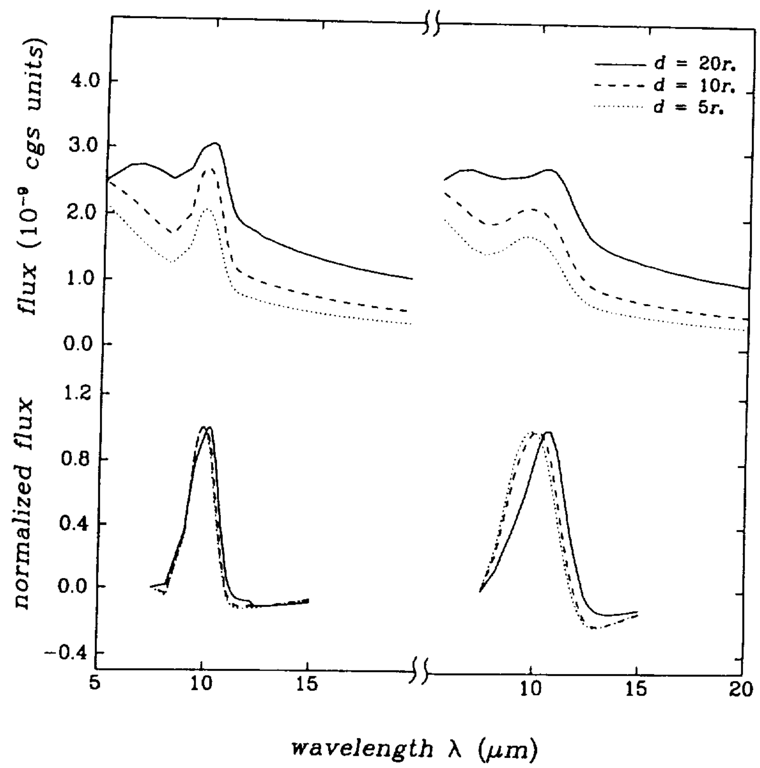

Effect of circumstellar shell distance (d) on the flux spectra of gaussian features of different intrinsic half–widths (σ): $\sigma = 0.5$ μm on the left panel and $\sigma = 1.0$ μm on the right. The normalized flux for the spectral feature is obtained by subtracting the local blackbody continuum from the spectra. Note that the wider feature on the right is more sensitive to variation in shell distances. Furthermore, the blue side of the narrower feature is affected much less than the red side by changes in the shell parameters. These two characteristics are observed in the silicate and SiC features of O–rich and C–rich cool stars respectively.